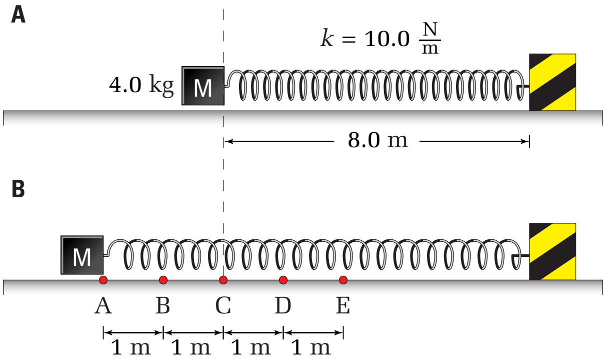
INVESTIGATION 5-C

Analyzing Periodic Motion

TARGET SKILLS
- Predicting
- Analyzing and interpreting
- Communicating results

Imagine that a spring is lying on a frictionless surface. One end is fastened to an immovable object and a 4.0 kg mass is attached to the free end, as shown in part (A) of the diagram. Then, the 4.0 kg mass is pulled 2.0 m to the left and held in place. You will follow the mass from the time it is released until it has travelled from Point A to point E, and then back to point A again, by determining the values of several of its variables at each labelled point. Let the positive direction be to the right and negative to the left.



Problem

Why does a spring continue to vibrate when stretched and then released?

Procedure

1. Prepare a table with the headings: Point, Extension or compression x(m), Restoring force F(N), Acceleration a(m/s^2), Elastic potential energy E_e(J), Kinetic energy E_k(J), Total energy E_t(J), Velocity $\vec{v}$(m/s), and displacement of the mass Δd(m). Provide nine rows under the headings.
2. Under the heading "Point," list the letters A through E in the first five rows. In the following four rows, to represent the return trip, list D through A, with a prime on each letter. In the column headed "Extension or compression," write the displacement, x, between the given point and the equilibrium position, C.
3. Use the mathematical relationships that you have learned in this chapter and previous chapters to calculate all of the other values in the table. Be sure to include positive and negative directions in your calculations, where appropriate. (Hint: Note that the mass was released *from rest* at point A.)

Analyze and Conclude

1. At which points in the cycle does the mass have **(a)** the greatest acceleration and **(b)** the greatest speed?
2. At which points in the cycle does the spring **(a)** exert the greatest restoring force, **(b)** possess the greatest amount of elastic potential energy, and **(c)** possess the least amount of elastic potential energy?
3. Why does the mass reverse direction at point E and then at point A′?
4. If there is no friction, what will happen to the motion of the mass and spring? Give reasons for your answer.
5. Plot both of the following relationships on one graph: acceleration versus position and velocity versus position. Use different colours and scales on the vertical axis for each of the plots.
6. Explain the relationships between velocity and acceleration at those points where velocity is zero and where acceleration is zero.
7. On one graph, again using different colours, plot elastic potential energy versus position, kinetic energy versus position, and total energy versus position. Discuss the significance of the relationships among these graphs.

PHYSICS FILE

The previous investigation asked you to imagine a frictionless surface. Physics courses are littered with frictionless surfaces and massless springs, strings, and ropes. Making these assumptions simplifies calculations and helps to focus on the essential ideas. Once the process becomes one of engineering and design, however, friction and masses of components become extremely important and cannot be ignored.

Periodic motion always requires a restoring force that depends on a displacement from a rest or equilibrium position in order to keep on repeating. In the case of a vibrating spring, this restoring force is provided by the attractive forces between atoms in the spring. In a resonating air column, such as in a sounding trumpet or clarinet, the restoring force is provided by collisions with other air molecules. In an oscillating pendulum, such as a mass swinging on a length of string, the horizontal component of the tension (T) in the string returns the mass to the centre.

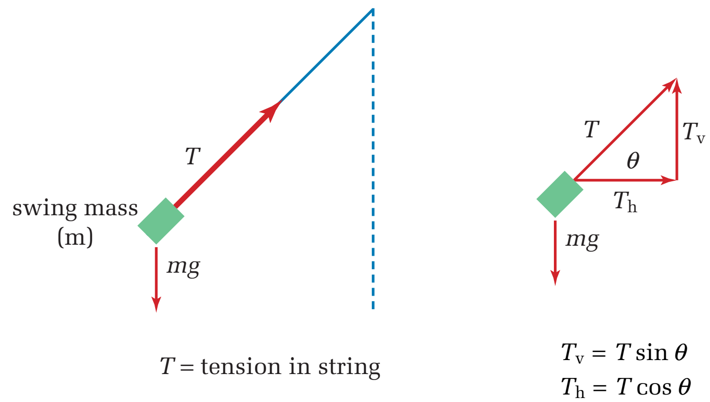


Figure 5.13 The horizontal component of the tension always acts in the direction of the equilibrium position of the pendulum. At the equilibrium position, the horizontal component of the tension is zero.

Periodic (or nearly periodic) motion is seen everywhere. Playground swings and teeter-totters exhibit periodic motion. Sound waves, water waves, and earthquake waves involve periodic motion. The electromagnetic spectrum from the radio waves that carry signals to our radios and televisions, to the gamma radiation emitted from radioactive materials, all embody periodic motion.

Figure 5.14 Waves on the ocean involve both transverse and longitudinal vibrations.